

PHONEMIC, ASSOCIATIVE, AND GRAMMATICAL CONTEXT EFFECTS WITH IDENTIFIED AND UNIDENTIFIED PRIMES*

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Six experiments are reported that assess priming effects on lexical decision (in Serbo-Croatian) when the context is identifiable (unmasked conditions) and when it is unidentifiable due to forward masking (masked conditions). Word acceptance is slowed by a phonemically similar context that is not masked but hastened by a phonemically similar context that is masked. Word acceptance is hastened by an associatively related context that is not masked; this facilitation is somewhat diminished when the context is masked. Finally, word acceptance is hastened by a grammatically related context that is not masked but is unaffected when the grammatical context is masked. These results can be rationalized in terms of a model of the language processor that maintains the autonomy of prelexical and postlexical levels but permits interaction among prelexical components.

Key words: lexical decision, priming, masking, visual word recognition

INTRODUCTION

It is well-known that perception of a word can be hastened or slowed if it is preceded by certain kinds of contexts. The kinds of contexts that matter (e.g., semantic, associative, grammatical, graphemic, phonemic), the way in which they matter (e.g., facilitating, inhibiting, or not affecting perception of the target), and the tasks for which they matter (e.g., target identification, rapid naming, lexical decision) have implications for theories of the language processor. In a model of the sort that Forster (1979, 1981) has proposed – in which lexical, syntactic, and message processors are assumed to be autonomous and arranged hierarchically – a growing consensus is, for example, that the naming and lexical decision tasks are both sensitive to prelexical and lexical influences, but only lexical decision is sensitive to postlexical influences (Stanovich and West, 1983; West and Stanovich, 1982, 1986). It has been shown that both tasks are affected by associative contexts (presumably lexical) while only lexical decision is affected by grammatical contexts (presumably post-lexical) (Carello, Lukatela, and Turvey, 1988; Seidenberg, Waters,

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Sanders, and Langer, 1984). More recently, phonemic similarity (independent of graphemic similarity) has been shown to affect both lexical decision and naming in the Serbo-Croatian language (Lukatela and Turvey, 1990).

Interestingly, a priming effect of orthographic similarity in English¹ is more likely to be observed if the context is masked so that it cannot be identified by the subject (e.g., Evett and Humphreys, 1981; Forster, 1987; Humphreys, Evett, Quinlan, and Besner, 1987). Humphreys *et al.* (1987) suggest that, because of the brief exposure of the context in masked conditions, context and target become a single event such that a graphemically similar context facilitates processing of the target letters while a dissimilar context disrupts it. This explanation does not seem obviously applicable, however, to the case of associative priming under masked context conditions (e.g., Evett and Humphreys, 1981; Fowler, Wolford, Slade, and Tassinari, 1981; Marcel 1983a, b) nor to the case of phonemic priming under unmasked conditions (Lukatela and Turvey, 1990). And it seems at odds with the finding of Fowler *et al.* (1981) that graphemically similar contexts – both masked and unmasked – slowed lexical decision. But because different investigators have employed different types of masking (forward and backward) and different response measures (reporting the letters in the target and lexical decision), it is not clear how the various priming results are to be accommodated within the same model of visual language processing.

In the present series of experiments we have chosen to apply Forster's methods of forward masking and lexical decision (e.g., Forster, 1987; Forster, Davis, Schoknecht, and Carter, 1987) to three types of priming – phonemic, associative, and grammatical. The three types of contexts were chosen because they have been characterized as operating at different levels of the language processor (e.g., Carello *et al.*, 1988; Gurjanov, Lukatela, Lukatela, Savić, and Turvey, 1985; Gurjanov, Lukatela, Moskovljević, Savić, and Turvey, 1985; Lukatela, Turvey, Feldman, Carello, and Katz, 1989; Lukatela, Feldman, Turvey, Carello, and Katz, 1989; Lukatela and Turvey, 1990) and all can be obtained reliably under normal, unmasked conditions using the Serbo-Croatian language.²

¹ While experiments with the Serbo-Croatian language show phonemic priming in the absence of graphemic similarity (Lukatela and Turvey, 1990), experiments with the English language tend to show no phonemic effect beyond what is attributable to graphemic similarity (e.g., Evett and Humphreys, 1981). This may be due to the different orthographies of the two languages. The Serbo-Croatian writing system is a "shallow" orthography (each letter has only one pronunciation, there are no double or silent letters, and there are no spelling exceptions) while the English writing system is relatively "deeper" (e.g., Lukatela and Turvey, 1980; Frost, Katz, and Bentin, 1987). While the phonological route to the lexicon appears to be obligatory for Serbo-Croatian, it may not be for English. There is occasionally evidence for a phonological route in English as well but this issue is beyond the scope of the present paper. The reader is referred to Lukatela and Turvey (1990) for a thorough discussion of the facts and arguments.

² With English, in contrast, only associative priming is robust. The grammatical effect tends to be small (Goodman, McClelland, and Gibbs, 1981; Seidenberg *et al.*, 1984; Wright and Garrett, 1984) and may be confounded with semantic effects (cf. Carello *et al.*, 1988). Phonemic priming depends on the extent to which phonemic and graphemic influences have been confounded (Evett and Humphreys, 1981) and may require complete phonological overlap (i.e., the use of homophones [Humphreys, Evett, and Taylor, 1982]).

Lexical decision was chosen because it is sensitive to both prelexical and postlexical effects. Forward masking was chosen because, unlike backward masking, it seems to produce priming that is qualitatively different from that obtained under unmasked conditions (compare Humphreys *et al.* [1987] with Fowler *et al.* [1981]).

In what follows, we describe a model of the language processor as it is understood currently for the Serbo-Croatian language, providing a summary of data supporting that characterization. Next, the possible role of forward masking in such a model is considered, together with predictions about its influence on the three types of context effects. Finally, those predictions are tested in six experiments, each of which is directed at one type of context effect either under masked-prime or unmasked-prime conditions.

A model of word processing with special reference to Serbo-Croatian

The basic model is patterned after Forster's (1979, 1981) proposal that lexical, syntactic and message processors are autonomous levels arranged hierarchically. The lexical processor finds meanings (lexical entries) for letter strings in a message by means of prelexical processes (a number of which are described below), without influence from the higher levels. The syntactic processor evaluates the grammatical structure of the lexical entities that are found and it does so without input from the message level. Finally, the message processor evaluates the semantic plausibility of the message.

Prelexical processes. We have begun to develop an interactive network model in the style of McClelland and Rumelhart (1981) for prelexical processing in the Serbo-Croatian language (Lukatela, Feldman *et al.*, 1989; Lukatela, Turvey *et al.*, 1989; Lukatela and Turvey, 1990). The prelexical mechanism comprises several successive layers of processing units, one each for features, letters, phonemes, and words. It is assumed that: (1) within a layer, connections can be either excitatory or inhibitory while, between levels, connections are only excitatory; (2) each unit is characterized by a resting level of activation in the absence of input; (3) a given unit's input is the weighted sum of inputs from the units to which it is connected; and (4) even though many units may be activated by a given input to the network, the time-varying aspects of excitation, inhibition, sending and receiving signals result in high levels of enduring activation for the few units that are most consistent with the input.

There are several potential sources of prelexical context effects: alphabetic, graphemic, phonemic, and associative. Alphabetic effects due to the use of two alphabets, Roman and Cyrillic, are illustrated most easily with phonologically ambiguous letter strings, those that are pronounced one way if read as Cyrillic and a different way if read as Roman. BETAP, for example, is pronounced /vetar/ if read in Cyrillic and /betap/ if read in Roman. In Cyrillic, it is a word meaning "wind" but in Roman it is a nonword. Decision latencies to VETAR, /vetar/, the phonologically unique Roman transcription of the word "wind", are considerably faster than latencies to BETAP. The phonological ambiguity effect (PAE) is reduced if preceded by a word or consonant cluster that specifies the alphabet of the word interpretation (Lukatela, Turvey *et al.*, 1989). Alphabetic effects are hypothesized to arise because of inhibitory connections between the Cyrillic letter units and the Roman letter units: Unique letters in the context inhibit the letter units of the other alphabet. Although this inhibition decays with time, some

activity is present when the phonologically ambiguous target appears. For BETAP preceded by a Cyrillic item, word units consistent with /b/ and /p/ in the first and last positions would be excited only weakly compared to situations where those phonemes had not been inhibited. At the word unit level, then, most of the competing processes concern word units excited by /v/, /ʒ/, /t/, /a/, and /ɪ/ in positions one through five, respectively.

The bi-alphabetic nature of the Serbo-Croatian language also permits investigations that distinguish graphemic and phonemic effects. They show that phonemic priming does not derive from graphemic priming. BALON and БАЛОН, both of which are pronounced /balon/, have an identical effect on decisions about BARON /baron/ (relative to ŠOFER or ШОФЕР, both of which are pronounced /ʃɔfɛr/) even though one shares four graphemes while the other shares only two (Lukatela and Turvey, 1990). The type of effect that phonemic priming has on lexical decision depends on the frequency of the target, and the position of the nonshared phoneme: (1) A rhyming context slows lexical decision to high frequency words but speeds lexical decision to low frequency words; and (2) for context–word pairs differing by only one phoneme, initial-different are speeded but mid- or final-different are slowed (Lukatela and Turvey, 1990).

A rhyming context slows decisions about high frequency targets because of inhibition at the word unit level. As argued by Colombo (1986), after a prime has been presented, the word unit for a phonemically similar target will already have received considerable excitation because it is consistent with most of the phoneme unit positions. It is characteristic of the competitive processes that word units receive inhibition that is proportional both to their frequency and their current level of excitation. The degree of the effect of the input to a unit is modulated by the unit's current activity level to keep the input to the unit from driving it beyond some maximum and minimum values (Grossberg, 1978). This amounts to a winnowing mechanism that reduces the number of physically similar word units that are active. For high frequency words, the high level of excitation automatically invites a large amount of inhibition. In order to be recognized, therefore, the target must overcome that inhibition and is slowed relative to situations where that word unit had not received excitation (Colombo, 1986; Lukatela and Turvey, 1990). A low frequency target does not have to overcome inhibition. Instead, because the appropriate word unit has been excited above the resting level, it is recognized more quickly. With fewer shared phonemes, the context's excitation of the target's word unit will be less. Consequently, in phonemically dissimilar contexts, high frequency targets will invite less inhibition and low frequency targets will have less excitation to take advantage of. Finally, the position of the unshared phoneme matters presumably because the word units, which comprise ordered phonemes, are sensitive to which positions are activated (Lukatela and Turvey, 1990).

Associative priming effects on lexical decision show strong facilitation (90 msec) relative to a neutral baseline comprising a row of Xs (Carello *et al.*, 1988). The effect is larger for phonologically ambiguous targets than for their phonologically unique counterparts (Lukatela, Turvey *et al.*, 1989). Whether or not the associate is written in the same alphabet as the target does not affect the amount of associative priming for phonologically unique targets (Lukatela, Turvey *et al.*, 1989). An associative context

works by raising the activation level of the target's word unit, thereby lessening the time for that unit to emerge in the competitive processes at that level (other word units will have been activated by the phoneme units, other associates will also be active, etc.).

Postlexical processes. Both syntactic and message processors are construed as carrying out automatic coherence checks that bias a general problem solver: Syntactically congruent or semantically plausible messages generate positive bias and incongruent or implausible messages generate negative bias. The automaticity of postlexical processes is implicated by a number of results in the Serbo-Croatian language, where syntactic violations are easy to produce because of its inflectional nature. Adjective–noun pairs must agree in gender (masculine, feminine, or neuter), case (e.g., nominative, dative, accusative, etc.), and number (singular or plural). Lexical decision to noun targets is slowed when the preceding adjective disagrees on one or more of these dimensions (Carello *et al.*, 1988; Gurjanov, Lukatela, Lukatela *et al.*, 1985; Gurjanov, Lukatela, Moskovljević *et al.*, 1985; Lukatela, Kostić, Todorović, Carello, and Turvey, 1987). Pronoun–verb pairs must agree in number and person; violations slow lexical decision (Carello *et al.*, 1988; Lukatela, Moraca, Stojnov, Savić, Katz, and Turvey, 1982). A grammatical congruency effect also is produced in preposition–noun pairs that do not agree in case (Lukatela, Kostić, Feldman, and Turvey, 1983).

In all of the aforementioned, syntactic coherence has an influence even though the lexical decision task itself does not require that syntactic relationship be taken into account. A syntactic coherence check appears to be an unavoidable, automatic aspect of language processing. Automaticity is also suggested by the fact that syntactic contexts do not place tight constraints on the universe of targets that can follow them legally. With a minimal grammatical context such as MOJ (“my”), for example, it is unlikely that expectancies about the target would be of much help because those expectancies would have to be so unfocused (e.g., all masculine nouns) (Lukatela, Carello, Kostić, and Turvey, 1988). Finally, all of these experiments used equal number of congruent and incongruent situations, and all but one limited the grammatical manipulation to a specific contrast (e.g., nominative vs. genitive, masculine vs. feminine). A congruent target of a particular case or gender or number, therefore, was not more likely than an incongruent target of a particular case or gender or number.³

Message level coherence checking appears to operate in much the same way. Lexical decisions about noun targets were faster (by about 64 msec) when they followed semantically plausible adjectives than when they followed semantically implausible adjectives (Lukatela *et al.*, 1988). The adjective contexts were chosen to be low

³ An experiment that manipulated the type (case, gender, or number) and number (zero, one, or two) of grammatical violations found that neither mattered to the size of the grammatical congruity effect (Lukatela *et al.*, 1987). The magnitude of the effect (18 msec) was small, however, in comparison to other experiments (differences on the order of 40 to 50 msec) in which only one type of disagreement ever occurred (cf., Gurjanov, Lukatela, Lukatela *et al.*, 1985). This suggests that although the syntactic coherence check is engaged automatically, experiment-wide expectations about the type of violation that can occur may focus attention on one dimension (Lukatela *et al.*, 1987).

constraint: Many targets were appropriate but no one was particularly predictable (e.g., BELI-GOLUB, "White pigeon" vs. VUNENA-ŠKOLA, "woolen school"). Again, expectancies would be too unfocused to be of much help. It appears that semantic coherence checks, too, are an automatic, unavoidable activity of the language processor.

The influence of masking on three types of context effects

Given the model of the language processor sketched in the foregoing, how should masking a prime so that it is not detectable affect the three types of priming? For phonemic priming, consider high frequency targets that differ from their contexts with respect to the middle consonant. As described earlier, such a relationship slows lexical decision relative to a phonemically dissimilar context. When the context is masked, the level of activation of the phonemes should be less and the level of activation of word units with phonemes in those positions should be less. Indeed, if the level of activation of the context's word unit does not exceed its threshold, then no word unit would survive the competitive processes, and no context should be detected. When the target comes along, its word unit is already activated above the resting level but the level is not so great as to invite much inhibition. Consequently, it should emerge from the competitive processes sooner than a target whose word unit had not been activated previously. Our first prediction is that masking a context should turn an inhibitory phonemic priming effect into a facilitatory effect.

For associative priming, facilitation is observed because the target's word unit has been activated above the resting level. When the context is masked, the overall levels of activation of the phoneme units and word units are again less. As before, activation of the context's word unit is not sufficient to emerge from the competitive processes but it still activates its associates to some degree above resting level. Therefore, we should still expect some facilitation relative to a target whose word unit had received no activation. The amount of facilitation may be less than in the unmasked case. Our second prediction is that masking an associative context may lessen the priming effect but it should remain facilitatory.

Finally, grammatical priming is the result of a positive bias from the syntactic coherence check for grammatically congruous context–target pairs and a negative bias for incongruent context–target pairs. When the context is masked, the overall levels of activation are less and no word emerges from the competitive processes at the word unit level. This means that the syntactic coherence check is carried out only on the targets and these are the same for congruous and incongruous situations. Our final prediction is that masking a grammatical context should eliminate the grammatical congruity effect.

We turn now to six lexical decision experiments. Experiments 1, 3 and 5 address phonemic, associative, and grammatical priming, respectively, under normal conditions with identifiable contexts. Experiments 2, 4 and 6 provide the masked prime counterparts.

EXPERIMENT 1

Ordinarily, priming effects are beneficial in that relative to the appropriate control, decision times are speeded up. An associatively related context and a grammatically congruent context speed up decisions relative, respectively, to an associatively unrelated context and a grammatically incongruent context. Interestingly, and importantly for present purposes, a phonemically similar context can either speed up or slow down lexical decision relative to a phonemically dissimilar context. As noted in the introduction, research by Lukatela and Turvey (1990) with Serbo-Croatian materials indicates that, for targets of relatively high frequency that differ from their contexts in the middle letter, phonemically similar situations produce slower lexical decisions than phonemically dissimilar situations. The first experiment re-affirms this observation.

Method

Subjects. Fifty-six high school students from the Fourth Belgrade Gymnasium served voluntarily as subjects. None had previous experience with visual processing experiments. Each was assigned to one of four counterbalancing groups according to his or her appearance at the laboratory.

Materials. Word targets consisted of 72 singular nouns of relatively high frequency (an average of 83 per million according to Lukić, 1983) in the nominative case. All were composed of five letters. Contexts were written in lower case Cyrillic and targets were written in upper case Cyrillic. (This manipulation reduces but does not eliminate graphemic similarity. Previous research has demonstrated, however, that there are no effects of graphemic similarity over and above the effects of phonemic similarity [Lukatela and Turvey, 1990].) One set of contexts was chosen to be phonemically identical to targets except for the middle letter (e.g., бaлoн–бAПoн, /balɔn/–/barɔn/, “balloon–baron”). A second set of contexts was chosen to be phonemically dissimilar to the targets, sharing no more than two phonemes (e.g., шoфep–бAПoн, /ʃɔfɛr/–/barɔn/, “chauffeur–baron”). Contexts and targets were not related in meaning. A corresponding set of pseudowords was generated by changing one letter in each of the target words. The replacement was an orthotactically and phonotactically legal letter. All letter strings were written in the Cyrillic alphabet.

Design. A given subject never encountered a context or target (word or pseudoword) more than once. Nor were a pseudoword and the source word from which it was derived presented to the same subject. But all subjects encountered both phonemically similar and phonemically dissimilar pairs and a given target appeared in both phonemically similar and phonemically dissimilar situations. This was achieved by using four counterbalancing groups. Each subject saw a total of 160 stimulus pairs.

Procedure. A subject sat before the CRT of an Apple IIe computer in a dimly lit room. A fixation point was centered on the screen. On each trial, the subject heard a brief warning signal, after which a context appeared for 500 msec centered above the fixation point. After an interstimulus interval of 100 msec a noun or pseudonoun appeared below the fixation point for 500 msec. Intertrial intervals were 2500 msec.

Subjects were instructed to decide as rapidly as possible whether or not the second stimulus (the one written in uppercase) was a word. Decisions were indicated by depressing a telegraph key with both thumbs for a “No” response or by depressing a key slightly further away with both forefingers for a “Yes” response. If the response latency was longer than 1400 msec, a message appeared on the screen requesting that the subject respond more quickly. That trial was then repeated, but only the first result was included in the analysis. To ensure that subjects were reading the contexts, a message appeared on the screen (every 10 to 20 trials) asking them to report the prime after the response had been made.

Results and discussion

Latencies in excess of 2000 msec or less than 250 msec were dropped from the reaction time analysis and included in the error analysis. This procedure applied to all of the experiments in the present series. Separate analyses of phonemic relatedness were performed on the acceptance and rejection latencies and errors. For words, phonemic relatedness was significant, $\min F'(1, 114) = 7.43, p < 0.01$, with words in phonemically similar contexts (808 msec) being accepted more slowly than words in phonemically dissimilar contexts (779 msec). There was no difference in the error analysis, $F < 1$ (4.96% and 4.07% for phonemically similar and dissimilar, respectively). Phonemic relatedness was not significant for pseudowords, $F < 1$ (both phonemically similar and dissimilar contexts averaged 835 msec.).

Consistent with previous findings (Colombo, 1986; Lukatela and Turvey, 1990), and with the model sketched in the introduction, phonemic similarity defined by an identity of phonemes with the exception of the middle phoneme slows lexical decisions to high frequency words. The pseudoword data, in which phonemic relatedness did not have an influence, can be understood within the same model. The pattern of excitation set up by the contexts *балон* and *шофер* will be the same as before. When the pseudoword target *БАФОН* appears following the phonemically similar context, its prelexical processing will be speeded up because four of its phoneme units are already above the resting level of activation. In contrast, the post-lexical processing to determine that *БАФОН* did not fully activate a word unit will be slowed, given that the word unit previously activated fully and those word units activated partially by *балон* (namely, *балон* and those units representing phonemically similar words) will be boosted by *БАФОН*. The prelexical benefits will be offset by the post-lexical costs. When *БАФОН* appears following the phonemically dissimilar context *шофер*, neither prelexical benefits (most of its phoneme units are at the resting level) nor post-lexical costs (no phonemically similar word units have been previously activated) are incurred. On balance, if the advantage gained at the phoneme unit level for *балон*—*БАФОН* is countered by less activity at the word unit level for *шофер*—*БАФОН*, then the two types of contexts would be expected to have equivalent effects.

EXPERIMENT 2

Masking the context to an appropriate degree should lessen the amount of inhibitory processes at the word unit level, so that the difference between phonemically similar and dissimilar contexts reduces to a difference at the phoneme unit level. If that is the case, then phonemically similar contexts should hasten lexical decision relative to phonemically dissimilar contexts.

Method

Subjects. Forty-five high school students from the Fourth Belgrade Gymnasium served voluntarily as subjects. None had previous experience with visual processing experiments. Each was assigned to one of four counterbalancing groups according to his or her appearance at the laboratory.

Materials and design. These were identical to Experiment 1.

Procedure. The procedure was the same as Experiment 1 with the following exception. The fixation point was followed by a forward mask, centered on the screen, consisting of a row of ten hash marks (#####) for 500 msec. This was followed immediately by the context for 80 msec and, immediately after that, the target for 500 msec, both in the same location as the mask had been. On the basis of a pretest with a different group of subjects, it had been determined that under these circumstances the prime could not be identified reliably. The error rate in deciding whether or not the prime was a word was of the order of 40%.

Results and discussion

Separate analyses of phonemic relatedness were performed on the acceptance and rejection latencies and errors. For words, phonemic relatedness was not significant by the min F' analysis (min $F' (1, 112) = 1.85, p < 0.20$), but was in the analysis by subjects, $F (1, 44) = 4.03, p < 0.05$, with words in phonemically similar contexts (754 msec) being accepted more quickly than words in phonemically dissimilar contexts (767 msec). In the error analysis, however, this pattern was reversed, $F (1, 44) = 4.53, p < 0.05$ (9.17% and 6.11% for phonemically similar and dissimilar, respectively). Neither of these were significant in the stimulus analysis: For latencies, $F < 1$; for errors, $F (1, 71) = 2.84, p < 0.10$. Phonemic relatedness was significant for pseudowords, min $F' (1, 97) = 3.79, p < 0.05$, with pseudowords in phonemically similar contexts (789 msec) being rejected more quickly than pseudowords in phonemically dissimilar contexts (815 msec). There were no differences in the pseudoword error analyses, min $F' < 1$ (4.07% and 4.91% for phonemically similar and dissimilar, respectively).

Masking the context hastened lexical decisions to at least some phonemically similar target words although the speed-accuracy tradeoff revealed in the error analysis mitigates this finding somewhat. The lack of a consistent effect with stimuli deserves comment. While it is known that frequency of word targets is relevant to whether phonemic priming is facilitatory or inhibitory (Colombo, 1986; Lukatela and Turvey, 1990, Experiments 3 and 4), the particular frequency cutoff that will support reliable effects is not yet well

established. If frequency is not controlled narrowly, priming effects may not be obtained for all stimuli. However, pseudowords (which have no lexical entries and, therefore, no word units to be inhibited) should show a reliable priming effect. They did and, in addition, showed no sign of a speed-accuracy tradeoff. How should the priming effect with pseudowords be interpreted? Suppose that masking a phonemically similar context results in (a) some activation of phoneme units of relevance to processing the pseudoword target, and (b) very little activation of word units phonemically similar to the target. Then, the possibility arises that prelexical target processing would benefit more than postlexical target processing would suffer (see discussion of the preceding experiment). The net advantage resulting from a masked, phonemically similar context would, in consequence, be positive. By the same line of argument, a pseudoword target following a masked dissimilar context would receive no benefits prelexically and suffer no special costs postlexically, with a net advantage of zero accruing from the preceding context.

Another way to view the effect of forward masking is in terms of conscious strategic processes. With weakly identified contexts, the subject is thwarted from developing processing strategies especially suited to the task. Under these conditions, automatic, involuntary mechanisms dominate processing of the target. The reversal of the direction of the phonemic priming effect from Experiment 1 to Experiment 2 would suggest, on this view of the role of masking, that negative phonemic priming is due to some strategy that is applied only when the subject is aware of the prime.

Returning to the effect with pseudowords, it is important to note that the form and identity priming found with English materials under forward masking often fails with nonword stimuli (e.g., Forster, 1987, Experiment 1). One reason for the positive outcome in the present experiment might be the proximity of the nonword stimuli to real words (hence our referring to them as pseudowords); in experiments that have failed to find priming effects under masking, the nonwords have tended to bear little resemblance to real words. Another reason might be differences in the lengths of the nonword stimuli. The present stimuli were five letters long whereas in Forster's (1987) experiment, for example, they were eight letters long. It is not clear, however, why either stimulus difference should lead to contrasting outcomes. The possibility remains that the contrast arises from a difference in the basis for priming, with the Serbo-Croatian case being phonemic, as argued, and the English case being orthographic.

EXPERIMENT 3

Let us now consider the priming due to association. If a context word precedes a target word with which it is associated, then processing the target should benefit from the prior activation of the target's lexical representation. Similarly, if the target is a pseudoword whose origin word is an associate of the context, then rejection of the target should be slowed because of the raised activation level of a lexical item. These expectations were evaluated in the third experiment.

Method

Subjects. Fifty-six high school students from the Fourth Belgrade Gymnasium served voluntarily as subjects. None had previous experience with visual processing experiments. Each was assigned to one of four counterbalancing groups.

Materials. Word targets consisted of 56 singular nouns in the nominative case, ranging in length from three to seven letters. Pseudowords were generated by replacing one letter in the root morpheme of the words with an orthotactically and phonotactically legal letter. Related contexts were chosen on the basis of a pretest in which a list of 120 words was presented to a group of 25 students enrolled in psychology at the University of Belgrade and 28 high school seniors at the Fifth Belgrade Gymnasium. For each word in the list, the students were asked to write the first five words that came to mind. First-, second-, and third-order associates were then presented to another group of 50 students from the same populations, who also were asked to write the first five words that came to mind. Response sheets from both tasks were inspected for symmetrical associates regardless of rank differences (e.g., first-order and third-order, third-order and second-order). Fifty-six of these were used, ranging in length from four to six letters. The pseudowords were paired with associates of the words from which they were derived.

Design. A given subject never encountered a given target word or pseudoword more than once, but each target word appeared in both related and unrelated conditions and each subject saw equal numbers of related and unrelated trials. This was achieved with four counterbalancing groups. Each subject saw a total of 160 pairs, 112 of which were used in the analysis (56 word–word and 56 word–pseudoword pairs) and 48 of which acted as fillers (24 word–word and 24 word–pseudoword pairs that did not conform to the similarity/dissimilarity criteria described above).

Procedure. The procedure was the same as in Experiment 1 with the following exceptions: Contexts appeared for 700 msec and targets appeared for 1400 msec.

Results and discussion

Separate analyses of associative relatedness were performed on the acceptance and rejection latencies and errors. Words in related contexts were accepted faster (781 msec) than words in unrelated contexts (873 msec), $\min F' (1, 82) = 23.74, p < 0.001$. The effect was also significant in the error analysis, $\min F' (1, 93) = 7.63, p < 0.01$, with fewer errors on targets in associated contexts (3.95%) than in non-associated contexts (11.73%). For pseudowords, rejections were slower in a related context (902 msec) than in an unrelated context (871 msec), $\min F' (1, 91) = 5.34, p < 0.05$. The error analysis did not reveal a significant effect, $\min F' < 1$.

A context word produces a certain pattern of activity at the word unit level. When it is followed by an associate, the pattern of activity facilitates recognition of that word relative to a word that is not related to the context because the associated target's word unit will already have received some activation. When that target is a pseudoword derived from an associate of the context word, however, that same activity adds clutter to the competitive processes and slows rejection relative to a pseudoword whose source word is unrelated to the context.

EXPERIMENT 4

Experiment 4 used the same context–target situations with the context masked. The activity level produced by the context is expected to be less and, consequently, all effects are expected to be less but in the same direction.

Method

Subjects. Twenty-four high school students from the Fourth Belgrade Gymnasium served voluntarily as subjects. None had previous experience with visual processing experiments. Each was assigned to one of four counterbalancing groups.

Materials and design. Same as in Experiment 3.

Procedure. The procedure was the same as in Experiment 3 but with the same masking characteristics as in Experiment 2.

Results and discussion

Separate analyses of associative relatedness were performed on the acceptance and rejection latencies and errors. Words in related contexts were accepted faster (656 msec) than words in unrelated contexts (700 msec), $\min F' (1, 78) = 5.74, p < 0.02$. This effect was not significant in the error analysis, $\min F' (1, 77) = 1.06, p > 0.20$, although the pattern was in the right direction (9.23% and 13.39% for words in related and unrelated contexts, respectively) and was significant in the subjects analysis ($F (1, 23) = 4.49, p < 0.05$). For pseudowords, rejections were slower in a related context (753 msec) than in unrelated context (733 msec), but not significantly so, $\min F' (1, 73) = 1.88, p > 0.20$. The error analysis did not reveal a significant effect, $\min F' < 1$.

As expected, the numerical patterns that were found under normal conditions – facilitation for words, inhibition for pseudowords – were repeated under masked conditions. They were less dramatic when the context was masked; facilitation was cut in half for words and by one third (and no longer significant) for pseudowords. But, because different groups of subjects were used in the two conditions, and the SOAs for unmasked (800 msec) and masked (80 msec) conditions differed, it is not appropriate to make much of this diminution except to note that it is consistent with the model. The main prediction was confirmed: Masking the context did not eliminate (or reverse) the associative priming effect for words.

EXPERIMENT 5

In the Serbo-Croatian language, investigations of grammatical influences on lexical decision have an advantage over English in that the syntactic manipulation is robust (usually around 40 to 50 msec), and it can be accomplished with single word contexts that do not introduce differences at the message level (Carello *et al.*, 1988). Experiment 5 used masculine singular nouns in either the dative (D) or accusative (A) case preceded by adjectives that either agreed or disagreed with respect to case. For example, MLADOM-

SLONU (“young elephant”) is D–D; MLADOG-SLONA is A–A; MLADOM-SLONA is D–A; and MLADOG-SLONU is A–D.

Method

Subjects. Sixty high school students from the Fourth Belgrade Gymnasium served voluntarily as subjects. None had previous experience with visual processing experiments. Each was assigned to one of four counterbalancing groups.

Materials. Twenty masculine singular nouns of five to seven letters were chosen along with twenty masculine singular adjectives, also of five to seven letters. Adjectives and nouns were not associates. Twenty pseudowords were generated by replacing one letter in the root morphemes of the words with a phonotactically and orthotactically legal letter. Congruent situations were created by pairing dative (D) adjectives and nouns or accusative (A) adjectives and nouns. Incongruent situations were created by pairing dative adjectives with accusative nouns or accusative adjectives with dative nouns.

Design. A given subject did not encounter a given target or context more than once but every subject saw congruous and incongruous situations and every target appeared in congruous and incongruous situations. Put differently, each subject saw the same adjectives, nouns, and pseudonouns as every other subject but not necessarily in the same grammatical case nor necessarily in the same dative–accusative permutation. This was achieved with four counterbalancing groups. Each subject saw a total of 160 experimental stimulus pairs (eight subsets of 20) and 12 filler pairs that were not used in the analysis.

Procedure. Same as in Experiment 3.

Results and discussion

Separate analyses of grammatical relatedness were performed on the acceptance and rejection latencies and errors. For words, grammatically congruent targets were accepted more quickly (698 msec) than grammatically incongruent targets (745 msec), $\min F' (1, 128) = 6.85, p < 0.001$. The main effect of target case was not significant, $\min F' < 1$.

For pseudowords, the congruity effect (with rejection taking longer in a congruent context (801 msec) than in an incongruent context (781 msec) was not significant, $\min F' < 1$. There were no significant effects in the error analysis.

EXPERIMENT 6

The expected grammatical congruity effect on words was obtained in Experiment 5. It is hypothesized that the grammatical congruity effect derives from a postlexical process that checks the grammatical fit between the context and the target. Accordingly, under conditions in which a context does not survive the competitive processes at the word unit level, no syntactic coherence check would occur and no grammatical congruity effect would be expected: Masking the contexts should eliminate the difference in lexical decision as a function of grammatically congruent and incongruent contexts.

Method

Subjects. Thirty-two high school students from the Fourth Belgrade Gymnasium served voluntarily as subjects. None had previous experience with visual processing experiments. Each was assigned to one of four counterbalancing groups according to his or her appearance at the laboratory.

Materials and design. Same as in Experiment 5.

Procedure. Same as in Experiment 5 but with the same masking characteristics as in Experiment 2.

Results and discussion

Separate analyses of syntactic relatedness were performed on the acceptance and rejection latencies and errors. There were no significant differences in any of the analyses, all $F < 1$. Words in congruent contexts averaged 766 msec; words in incongruent contexts averaged 762 msec. Pseudowords following the two contexts both averaged 860 msec. The lack of a grammatical congruity effect for word targets under the masking conditions of the present experiment is consistent with the idea that, because the context's word unit did not reach its threshold, no postlexical coherence check was conducted.

GENERAL DISCUSSION

Contextual information influences word perception in tasks such as lexical decision that, superficially, do not require that context be considered. The reason, of course, is that since contextual information must be taken into account in natural language perception, the normal automatic operations of the language processor cannot be circumvented for a contrived experimental task. But how contextual information exerts its influence has been a subject of debate. The present series of experiments addressed this question with masked and unmasked contexts. The results, in brief, were these: (1) an inhibitory phonemic priming effect under unmasked conditions became a facilitatory effect when the context was masked; (2) a facilitatory associative priming effect under unmasked conditions remained facilitatory, though somewhat smaller, when the context was masked; and (3) a facilitatory grammatical priming effect under unmasked conditions was eliminated by masking the context.

The three types of context effects and how each is influenced by forward masking are rationalized in terms of a model of the language processor that we have been developing for the Serbo-Croatian language (patterned after similar efforts for English). The basic model proposes three major levels: lexical, syntactic, and message (Forster, 1979, 1981). While these levels are held to be autonomous, with higher levels not influencing processing at lower levels, processes within each of these levels can be interactive.

Let us summarize first the arguments with respect to phonological priming. A phonemically similar context word will activate partially a number of word units, namely, those that have some of the same phonemes in the same positions as the context word.

One of these partially activated word units represents the target. If the target is a very frequent word, the activation level of its representation will be relatively high and, by Grossberg's (1978) principle of self-modulation, the inhibition its word unit receives from other units during the processing of the context word will also be relatively high. As a result, when the target occurs it is processed in circumstances in which its word unit is inhibited, slowing its identification. A phonemically dissimilar context, in contrast, would not activate the target's word unit. The target's word unit would not, therefore, be inhibited prior to the occurrence of the target. By masking a phonemically similar context, the activation of its word unit is lessened and, thereby, the amount of inhibition of the target's word unit is lessened. Under masking, phonemically similar and dissimilar contexts will, therefore, be more alike in terms of the amount of target inhibition with which they are associated. With reduced word level inhibition, our model suggests that a masked phonemically similar context could be of benefit to a high frequency target by priming the phoneme units relevant to the processing of the target. The upshot is a reversal under masking of the result obtained under nonmasking; to repeat, masked phonemically similar contexts speed up lexical decision whereas nonmasked phonemically similar contexts retard lexical decision.

Let us now summarize the arguments with respect to the other two kinds of priming. Associative priming is said to be focused at the word unit level. The difference between associatively related and unrelated contexts is how much excitation is directed at the target's word unit. This is simply scaled down for masked contexts. Grammatical priming is said to arise post-lexically. Outputs of prelexical processes are evaluated for how they relate, first, grammatically, and second, pragmatically. A general problem solver receives negative bias when the coherence check reveals incongruity and positive bias when that check reveals congruity. It is hypothesized that the difference is eliminated when the context is masked because the context does not survive prelexical processing (its word unit does not reach threshold) and its relationship to the target cannot be evaluated.

The model just described is a hybrid of two generic models that typically are treated as mutually exclusive alternatives. Although the sorts of context effects that we have been calling prelexical require interaction between phoneme units and word units, those layers of units are circumscribed within a level that is itself independent of the syntactic and message levels of the language processor. Data available thus far do not demand further interaction between prelexical and postlexical processes (cf. McClelland, 1987).

Masking techniques have been considered useful to elucidating various aspects of the language processor. One of the reasons for using a masking paradigm, for example, is to investigate context effects when subjects are unaware of the contexts (see Holender [1986] for a critique of methods of assessing awareness). It has been argued that only automatic context effects survive under masked conditions, so that, if an effect is altered, its normal occurrence is at least partly under strategic control (cf., Neely, 1977; Posner and Snyder, 1975). This logic would have us conclude that grammatical priming effects, because they were eliminated with masked contexts, are normally the result of some strategy on the part of subjects. We have pointed out independent grounds for considering grammatical priming to be automatic, however. (To reiterate, the grammatical contexts that produce a congruity effect are not predictive of their targets and a given

type of incongruent situation is as expected as a given type of congruent situation.) In any event, the elimination of a grammatical congruity effect following masking is predicted by a model that holds such effects to be automatic — that is, a strategic interpretation is not an inevitable consequence of the masking results.

Another reason for using a masking paradigm is to try to isolate when and where certain processes occur relative to other processes (e.g., Marcel, 1983b; Turvey, 1978). To use masking effectively for that purpose, however, a variety of timing and energy relationships between target and mask must be considered carefully under a particular style of presentation for each individual subject (Michaels and Turvey, 1979). Depending on stimulus onset asynchrony (SOA), lexicality of the target, left or right visual field presentation, monoptic or dichoptic masking conditions, and luminance ratios between target and mask may or may not matter (Michaels and Turvey, 1979). The present experiments, in being limited to forward masking with the same SOA for all subjects, begin to address the general issue of priming effects with degraded contexts. Although they support the contention that where the mask and context operate in the hierarchical structure of the language processor determines whether or not a given context can survive to have an influence, the requisite parametric studies remain to be done.

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